PNEUMATIC MICROFLUID DRIVING SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a pneumatic microfluid driving system and method. More specifically, for providing different volumes and directions of combination models of airflow by using a servo-device, corresponding with an air gallery structure and a connecting channel which is co-constructed inside the micro-reaction module, thus the fluid (samples/reagents) inside the microfluid channel in the micro-reaction module shall be led to cause minute microfluid movement effects like proceeding, receding and stopping.

DESCRIPTION OF RELATED ARTS

Lab. On a Chip refers to a process that, by concentratively employing a series of inter-connecting biochemical experiments on miniaturized chips, re-enacts the operational procedures of the overall biochemical experiments via particularly designed serving system, a result that resembles an automatized laboratory with complete functions being miniaturized in chips, wherein the biochips for both nucleotide sample processing and DNA-based reaction testing were developed at the earliest and closest to mass production. For such kind of chips, the microfluid driving device for introducing samples or biochemical reagents to move inside chips is a primarily necessary technology. Therefore, how to avoid samples and biochemical reagents mutually contaminating each other has become an important consideration for designers to pay close attention.

Common design strategies can be divided into three main categories:

1. On-chip mechanical micropump;
2. On-chip electrokinetic micropump; and
3. External servo-system.

The above three main categories are to be described in detail as follows:

1. On-chip mechanical micropumps

By employing micro-machining technology, the on-chip mechanical micropumps can be built directly onto chips, and for this kind of design to work, moveable parts are to be constructed inside chips. The U.S. Patent No. 5,529,465, invented by Roland Zengerle et al., discloses the electrostatistically driven diaphragm micropump, with the main body comprising four layers of silica structure; when electricity with magnitude of 50V, 400Hz is introduced thereon, the attraction of the sporadic dielectric is caused between the upper two layer structures, thus, in accordance with two passive check valves, the pumping action is completed through means of circulating and exchanging, with the working volume reaching 350 μ l/min.

The U.S. Patent 5,705,018, invented by Frank T. Hartley, discloses a micromachined peristaltic pump, which is another micropump design. Flexible conductive strips are constructed on the sidewalls of the channel on chips, thus when a sequential voltage is applied to the series of strips, the membrane is pulled into the channel portion of each successive strip to achieve a pumping action. The voltage pulse phases are to be carefully controlled, with the peak value of 100V and the working volume 100 μ l/min.

Both the aforementioned two on-chip mechanical micropumps have complicated structure, a drawback that makes them difficult to clean and produce, with reasons as follows:

It is almost out of the question to repetitiously apply samples from different patients on the same chip with on-chip mechanical micropumps, because it is quite difficult to clean up the samples or biochemical reagents left from the previous use, for moveable elements exist in the complicated microstructures. Yet, provided that chips with on-chip mechanical micropumps are to be used as disposable, the production cost of such disposable chips immediately becomes a major issue. Since either on-chip mechanical micropumps or micromachined peristaltic pumps involves in complicated production processes or expensive special material, characteristics that tremendously increase the production cost for these two kinds of micropumps, the result is to be in contradiction to the original appeal of disposable chips.

2. On-chip electrokinetic micropumps

Electrokinetic micropumps are of non-mechanical micropumps, with no moveable elements necessary in the device. Three kinds of common operations are: electro-osmosis ("EO"), electrohydrodynamics ("EHD") and electro-phorosis ("EP").

The U.S. Patent No. 5,632,876 with the title of "Apparatus and Methods for Controlling Fluid Flow in Microchannels", invented by Peter J. Zanzucchi et al., discloses the combined application of both EO and EHD. Two pairs of electrodes are constructed inside the channel on a chip, wherein one pair of electrodes is constructed to be nearer to each other, and deep into fluid in the channel. When a high voltage is applied, the two electrodes in contact with the fluid, form an electric circuit with surrounding fluid, and at the same time liquid surrounding the two electrodes is brought to flow in the direction opposite to that of the electric current, which is the EHD pumping.

Another pair of electrodes is constructed to be farther to each other, with electrodes coming into contact with only the sidewalls. When high voltage reaching hundreds or thousands of volts is conducted, the sidewalls are first being electrically charged, with the charged surfaces of the two electrodes being distributed with negative and positive electric charges. At this time, the charged surface of the negative electrode with positive charges will attract ions with negative electricity within fluid, thus causing fluid to move along as well, which is the EO pumping. The essential part of the invention is to combine the two micropumping effects of creating two flows with opposite directions, thus producing the channeling and controlling results of propelling, retrieving and stopping microfluid by the different forces of the two aforementioned pumping methods. Furthermore, the EO fluid has to be one that contains the polar solution having electrically charged ions, whereas the EHD fluid has to be one that contains non-polar solution, like organic solutions. Thus the invention claims that it is applicable to either polar or non-polar fluids when the two pumping methods are combined.

The thesis presented by Paul C. H. Li and D. Jed Harrison in 1997 ("Transport, Manipulation and Reaction of Biological Cells On-chip Using Electrokinetic Effects", Anal. Chem. 1997, 69, 1564-1568) discloses the combined application of both EO and EP pumping methods. The principle for EP pumping is quite unsophisticated comparing to other pumping methods. The electrically charged ions in solvents can be directly attracted and thus moved by electrodes, therefore the direction of movement shall be opposite to the EO direction. The key point is that what EO or EP pumping methods move are

electrically charged ions in solvents but not solvents themselves, thus the main effect of this experiment is not the channeling of the microfluid, but the moving of canine erythrocyte et al. existed in solvents. The result of the experiment shows that, by utilizing the difference of EP and EO forces between intersecting channels, the canine erythrocyte et al. are to be easily channeled, re-directed and even sorted.

The designs of the aforementioned on-chip electrokinetic micropumps have drawbacks as follows:

From the production point of view, the structure of electrokinetic micropumps is of the most unsophisticated comparing to other micropumps, thus with the lowest production cost. Yet there are limitations as to the aspect of the application. First, solvents have to be filled in the channel, thus samples or biochemical reagents are not to be filled into an empty channel; second, the effect of EHD pumping method in terms of moving fluid is very limited, and the main object for moving by EO and EP pumps is electrically charged ions in fluid but not fluid itself, thus the effects of the aforementioned three pumping methods for moving fluid are not prominent (approximately 10 μl/min). In addition, such three forces can only work in infinitesimal channels (100 μm diameter), and voltage differences from hundreds to thousands of volts should be conducted within very short distances, thus the operation cost cannot be lowered; finally, the EHD micropumps can only be applicable to non-polar organic solvents, and the EO and EP micropumps can only be applicable to polar solvents having electrically charged ions, also the ion density of solvents shall seriously affect the effectiveness of propulsion for such micropumps. As a result, problems concerning the channeling and controlling of fluid by such pumps shall emerge provided that samples with complicated components or reactive reagents are introduced, or variations of ion density occur during the process of reaction.

3. External servo-system

It is the simplest idea to solely use the external servo-system for channeling fluid. Apparently, no initiating elements are needed inside chips, thus the structure of chip can be simple with low production cost. Also it is of no need to utilize micro-processing technology to produce external servo-systems. In addition, external servo-systems can be used repeatedly for they do not come

into contact with samples or biochemical reagents, the most feasible design strategy in terms of the disposable biological chips for operating the biochemical reaction-testing.

However, the problem lies in the world-to-chip interface, that is, how to connect common-sized conveying channels (fluid conveyed can be gases or the reagents themselves) onto the micro-sized chips involves a series of complicated micro-processing technology. In 1998, N.J. Mourlas et al. exhibited designs of connectors between all kinds of channels and chips (Novel Interconnection and Channel Technologies for Microfluidics, Proceedings of the μ TAS '98 Workshop, 1998, 27-30).

Since pressure heightens significantly when fluid is filled into the micro-channels or micro-reaction tanks in chips, the specification requirement for the connecting points between channels and chips is strict (leakage test: 60 psi, pull test: 2N). Generally epoxy resin is used for sealing and strengthening the connecting points between channels and chips. Such design utilizes the Deep-Reactive Ion Etching (DRIE) to define the inserting point of the channel on the chip, and then the channel is made through using injection molding on polyoxymethylene plastic and inserted into the coupler; though the channel is to be directly inserted into the coupler, the durable connection is only completed after being heated to 250° C, a design that still has drawbacks of complicated production process and limited application.

SUMMARY OF THE INVENTION

The main object of the present invention is to provide a pneumatic microfluid driving system, comprising a servo-device for providing different combination models of airflows, an air gallery structure for receiving said airflow, and a connecting channel for connecting said air gallery structure and the fluid area for circulating the airflow.

The servo-device comprises an air compressor for providing combination models of airflow having various volumes and directions, and a buffer tank for stabilizing airflow sent out by said air compressor.

The air gallery structure comprises a suction component for sucking out fluid, and an exclusion component for excluding fluid.

The suction component includes an air gallery for receiving airflow provided by the servo-device, and a micro-channel for connecting the air gallery to introduce the airflow.

The airflow introducing is to suck out the airflow from the end of the micro-channel toward the direction of the air gallery.

The exclusion component includes an air gallery for receiving airflow provided by the servo-device, and a micro-channel for connecting the air gallery to introduce the airflow.

The airflow introducing is to exclude airflow from the air gallery toward the direction of the end of the micro-channel.

The connecting channel can be of different ways of connection, e.g., T-shape connection or parallel connection.

The connecting channel with parallel connection can be of suction type, intermediate type or exclusion type, depending on various needs of actual situations.

The end of the connecting channel can be connected to the reaction area that is to be driven from the outside.

The fluid area can be the microfluid channel.

The air gallery structure, connecting channel and the fluid area can be formed integrally.

The airflow combination models refers to the velocity combinations of the inlet airflow inputted into said suction component and said exclusion component of said air gallery structure.

The other object of the present invention is to provide a pneumatic microfluid driving system constructed on micro-reaction modules, comprising a servo-device for providing different combination models of airflow, an air gallery structure, constructed inwardly on the micro-reaction module for

receiving said airflow, and a connecting channel, co-constructed in the micro-reaction module to connect said air gallery structure and the reaction area on the micro-reaction module for circulating the airflow.

The servo-device comprises an air compressor for providing combination models of airflow having various volumes and directions, and a buffer tank for stabilizing airflow sent out by the air compressor.

The air gallery structure comprises a suction component for sucking out fluid on the micro-reaction module, and an exclusion component for excluding fluid the micro-reaction module.

The suction component includes an air gallery for receiving airflow provided by the servo-device, and a micro-channel for connecting the air gallery to introduce the airflow.

The airflow introducing is to suck out the airflow from the end of the micro-channel toward the direction of the air gallery.

The exclusion component includes an air gallery for receiving airflow provided by the servo-device, and a micro-channel for connecting the air gallery to introduce the airflow.

The airflow introducing is to exclude the airflow from the air gallery toward the direction of the end of the micro-channel.

The connecting channel can be of different ways of connection, e.g., T-shape connection or parallel connection.

The connecting channel with parallel connection can be of suction type, intermediate type or exclusion type, depending on various needs of actual situations.

The reaction area contains the microfluid channel.

The micro-reaction modules can be all kinds of miniaturized chips used for the purposes of various reactions or analyzing, e.g., lab-on-a-chip and biochips. The end of the connecting channel can be connected to the microfluid channel

on the reaction area.

The fluid can be samples or reagents.

The air gallery structure, connecting channel and the microfluid channel can be formed integrally on the micro-reaction module.

The airflow combination models are the velocity combinations of airflow inputted into the suction component and exclusion component of the air gallery structure.

Yet another object of the present invention is to provide a method for driving pneumatic microfluid, comprising the usage of the servo-device, for providing different combination models of airflow, and then airflow is introduced into the air gallery structure; the fluid inside the microfluid channel shall be droved, by airflow circulated in the connecting channel, to cause minute microfluid movement effects like proceeding, receding and stopping. The present invention is particularly suitable for all kinds of micro-reaction modules for biochemical analysis and operations, with the effective outcomes of simplifying the production procedures and lowing the costs.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention will become better understood with regard to the following description, appended claims and accompanying drawings that are provided only for further elaboration without limiting or restricting the present invention, where:

Fig. 1 shows a schematic diagram of the pneumatic microfluid driving system of the present invention;

Fig. 2 shows an equipment device diagram of the pneumatic microfluid driving system
of the present invention constructed upon a micro-reaction module;

Fig. 3(A) shows a structural view of the suction component in the air gallery structure;

Fig. 3(B) shows a structural view of the exclusion component in the air gallery

structure;

Fig. 4(A) shows a view of both the pressure field and the airflow field after airflow is introduced into the suction component shown in Fig. 3(A);

Fig. 4(B) shows a view of both the pressure field and airflow field after airflow is introduced into the exclusion component shown in Fig. 3(B);

Fig. 5 shows a design diagram of both the air gallery structure and the T-shape connecting channel in the pneumatic microfluid driving system;

Fig. 6(A) shows another embodiment of the connecting channel shown in Fig. 5, which is a diagram of the suction-type connecting channel;

Fig. 6(B) shows yet another embodiment of the connecting channel shown in Fig. 5, which is a diagram of the intermediate-type connecting channel;

Fig. 6(C) shows another embodiment of the connecting channel shown in Fig. 5, which is a diagram of the exclusion-type connecting channel;

Fig. 7 shows the different velocities produced at the end of the connecting channel in accordance with various types of connecting channels under different airflow inlet velocity in the pneumatic microfluid driving system of the present invention;

Fig. 8(A) shows a diagram of constructing the pneumatic microfluid driving system of the present invention on the micro-reaction module;

Fig. 8(B) is a photographic view of Fig. 8(A); and

Fig. 9 shows a photographic view of the fluid driving result for the dotted-line portions in Fig. 8(A).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a pneumatic microfluid driving system and method, and the merits and characteristics are to be further understood through detailed explanation as follows in accordance with drawings.

Fig. 1 shows the pneumatic microfluid driving system 100 of the present invention, comprising: a servo-device 1 for providing different combination models of airflow, an air gallery structure 2 for receiving said airflow, and a connecting channel 3for connecting said air gallery structure 2 and the fluid area 5 for circulating the airflow.

The servo-device 1 comprises an air compressor 11 for providing airflow combination models having various volumes and directions, and a buffer tank 12 for stabilizing airflow sent out by the air compressor 11.

The air gallery structure 2 comprises a suction component 21 for sucking out fluid, and an exclusion component 22 for excluding fluid.

The pneumatic microfluid driving system and method of the present invention utilizes the servo-device 1 to introduce airflow combination models having different volumes and directions, via the tube 10, into the suction component 21 and the exclusion component 22 inside the air gallery structure 2; and then airflow with specific flowing velocity is to be blown out via the end 26 of the connecting channel 3, for driving fluid on the fluid area 5 to produce the minute effects of microfluid movement as proceeding, receding and stopping. The fluid area 5 can be of microfluid channels.

The airflow combination model refers to the combination of airflow velocities from both the suction component 21 and the exclusion component 22 inside the air gallery structure 2, which are the inlet velocity Vs and Ve of the suction component 21 and the exclusion component 22 respectively.

Fig. 2 shows a schematic diagram of the pneumatic microfluid driving system 200 of the present invention constructed upon a micro-reaction module, at least comprising: a servo-device 1, for providing different combination models of airflow groups, a air gallery 2, constructed inwardly on the micro-reaction module 20 for receiving said airflow, and a connecting channel 3, co-constructed in the micro-reaction module 20 to connect said air gallery 2 and the reaction area 4 on the micro-reaction module 20 for circulating the airflow.

The servo-device 1 comprises an air compressor 11, for providing airflow combination models having various volumes and directions, and a buffer tank

12 for stabilizing airflow sent out by the air compressor 11.

The air gallery structure 2 comprises a suction component 21 for sucking out fluid on the micro-reaction module 20, and an exclusion component 22 for excluding fluid the micro-reaction module 20.

The pneumatic microfluid driving system 200 of the present invention constructed upon a micro-reaction module is to follow the operational procedure that first, the servo-device 1 is utilized to introduce airflow combination models having different volumes and directions, via the tube 10, into the suction component 21 and the exclusion component 22 inside the air gallery structure 2; and then airflow with specific velocity is to be blown out via the end 26 of the connecting channel 3, for driving fluid on the reaction area 4 to produce the minute effects of microfluid movement as proceeding, receding and stopping.

The reaction area 4 may contain microfluid channels.
The end 26 of the connecting channel 3 can be connected to the microfluid channel on the reaction area 4.

The micro-reaction modules can be all kinds of miniaturized chips used for the purposes of various reactions or analyzing, e.g., lab-on-a-chip and biochips.

The fluid can be samples or reagents.

The air gallery structure, connecting channel and the fluid area can be formed integrally on the micro-reaction module.

The airflow combination model refers to the combination of airflow velocities from both the suction component 21 and the exclusion component 22 inside the air gallery structure 2, which are the inlet velocity Vs and Ve of the suction component 21 and the exclusion component 22 respectively.

Fig. 1 and Fig. 2 show two different embodiments for the pneumatic microfluid driving system of the present invention. In Fig. 1, the pneumatic microfluid driving system of the present invention is not constructed upon the micro-reaction module, thus it can be extensively applied upon fluid areas of any outside model, e.g., the pneumatic microfluid driving system can be

outwardly connected to fluid areas, or to microfluid channels on chips. In Fig. 2, the pneumatic microfluid driving system of the present invention is constructed upon the micro-reaction module, thus the microfluid channel, air gallery structure and the connecting channel can be formed integrally; also the structures on top of the micro-reaction modules can be designed by using all kinds of production technology in accordance with actual needs, which can be mass produced to be as disposable micro-reaction modules.

Fig. 3(A) shows the structural view of the suction component 21 in the air gallery structure 2, wherein the suction component 21 comprises an air gallery 23 for receiving airflow provided by the servo-device, and a micro-channel 25 for connecting the air gallery 23 to introduce airflow.

The introducing of airflow is to suck airflow from the end of the micro-channel 25 toward the airflow channel 23 (the direction pointed by the arrow in Fig. 3(A)).

Fig. 3(B) shows the structural view of the exclusion component 22 in the air gallery structure 2, wherein the exclusion component 22 comprises an air gallery 24 for receiving airflow provided by the servo-device, and a micro-channel 25' for connecting the air gallery 24 to introduce airflow.

The introducing of airflow is to exclude airflow from the air gallery 24 toward the end of the micro-channel 25' (the direction pointed by the arrow in Fig. 3(B)).

The principles of the aforementioned introducing of airflow are to be elaborated as follows in accordance with Fig. 4(A) and Fig. 4(B):
Fig. 4(A) shows the value simulation results regarding the pressure and velocity of the suction component 21, which manifests that, when airflow is blown into the air gallery 23, the velocity of airflow increases after flowing through the throat portion 27, for the sectional area of the air gallery 23 becomes smaller; therefore, according the Bernoulli's equation concerning the pressure gradient distribution, a low pressure zone is to be formed at the throat portion 27, thus creating the phenomenon of suction, which is shown in Fig. 4(A).

Fig. 4(B) shows the value simulation results regarding the pressure and

velocity of the exclusion component 22, which manifests that, when airflow is blown into the air gallery 24, airflow in the air gallery 24 and the micro-channel 25' is to form the pressure gradient according the Bernoulli's equation, thus creating the phenomenon of exclusion, which is shown in Fig. 4(B).

Therefore, the suction and exclusion of airflow can be controlled through the specific designs of the suction component 21 and the exclusion component 22, in accordance with the Bernoulli's equation.

Fig. 5 shows a design diagram of both the air gallery structure 2 and the T-shape connecting channel 3 in the pneumatic microfluid driving system of the present invention. Airflow sent out from the servo-device 1 is to be respectively introduced into two air galleries 23 and 24, with specific velocity Vs and Ve. When the velocity Vs of the airflow blown in of the suction component 21 is zero (Vs=0), it is to be the OFF Mode; when the velocity Vs of the airflow blown in of the exclusion component 22 is not zero ($Ve \neq 0$), it is to be the Exclusion Mode. Conversely, when $Vs \neq 0$ yet Ve=0, it is to be the Suction Mode. Therefore, the velocity of airflow at the end 26 of the connecting channel 3 can be controlled by altering all kinds of models of different airflow combination (Ve/Vs).

The dotted-line portions in Fig. 5 refers to the T-shaped connecting channel 3, which can be replaced by those having different shapes according to specific needs; for example, the connecting channel 3, shown in Fig. 6(A) to 6(C), is to connect in parallel, wherein the connecting channel 3 shown in Fig. 6(A) is of a suctorial connecting channel, with the exclusion/suction ratio less than 1, thus having better suctorial effect; the connecting channel 3 shown in Fig. 6(B) is of an intermediate connecting channel, with the exclusion/suction ratio close to 1; the connecting channel 3 shown in Fig. 6(C) is of an exclusive connecting channel, with the exclusion/suction ratio larger than 1, thus having better exclusive effect.

Fig. 7 shows the different velocity produced at the end 26 of the connecting channel in accordance with various types of connecting channels under different airflow-introducing velocity (Ve or Vs) in the pneumatic microfluid driving system of the present invention, wherein (a) is of a T-shaped connection; (b) to (d) is of connection in parallel, whereas (b) is of a suctorial connecting channel, (c) is of an intermediate connecting channel, and (d) is of

an exclusive connecting channel. The result in Fig. 7 shows that, the pneumatic microfluid driving system of the present invention, on which various types of connecting channels, can acquire proper fluid driving velocity based upon actual operational needs.

The other object of the present invention is to provide a pneumatic microfluid driving method that, by using the servo-device 1 to provide different volumes and directions by combination models of airflow; when different models of airflow combination are to be blown, via the side of the micro-reaction module 20, into the air gallery structure 2 in the model, the airflow is to form the pressure gradient according to the Bernoulli's equation, through the structural design of suction component 21 and the exclusion component 22 in the air gallery structure 2; thus the effects of suction and exclusion are to be achieved. With the variations of ratios between suction and exclusion, the fluid inside the microfluid channel in the micro-reaction module 20 shall be led to minute microfluid movement effects like proceeding, receding and stopping. No connecting circuits are needed between the servo-device 1 and the micro-reaction module 20, and no active components are not needed in the micro-reaction module 20. The present invention is particularly suitable for all kinds of micro-reaction modules for biochemical inspections and operations, with the effective outcomes of simplifying the production procedures and lowing the costs.

The pneumatic microfluid driving system and method of the present invention are to be further understood through the embodiments as follows.

First Embodiment

This embodiment refers to the pneumatic microfluid driving system of the present invention being constructed on micro-reaction modules, with the equipment device diagram thereof shown in Fig. 2. Yet the connecting channel 3 used in this embodiment is of a suctorial connecting channel with connection in parallel (as shown in Fig. 6(A)), and integrally formed with the suction component 21, the exclusion component 22 and the microfluid channel 29, as shown in Fig. 7. Fig. 8(A) shows the schematic diagram as to the suction component 21, the exclusion component 22, and the connection between the connecting channel 3 and the microfluid channel 29 in the air gallery structure co-constructed on the micro-reaction module 20, wherein the

inner diameter of the microfluid channel is 600 μ m, and the air gallery structure's length is to be 21 mm, along with the width being 12.9 mm. Fig. 8(B) is a photographic view of Fig. 8(A).

The material for the microfluid module is made of PMMA (Polymethyl methacrylate).

In this embodiment, the fluid to be driven is first to be poured into the sample storage tank 30, and then when different models of the combination models of airflow groups are provided by the servo-device and are blown, via the side of the micro-reaction module 20, into the air gallery structure 2 in the model. The sample stored in the sample storage tank 30 is to be led, via the connecting channel 3, to minute microfluid movement effects like proceeding, receding and stopping in the microfluid channel 29, effects that are shown in Fig. 9.

Items (a) to (i) in Fig. 9 show the modes of movement by the sample in the microfluid channel 29 (the dotted-line portion in Fig. 8(A)). Item (a) represents the beginning mode, items (b) to (d) the mode of sample's being moved forward (the proceeding movement of fluid), item (e) the stopping mode (the stopping movement of fluid), and items (f) and (i) the mode of receding by the sample (the receding movement of fluid).

Therefore, the results of this embodiment manifest that fluid can easily be controlled by the pneumatic microfluid driving system and method of the present invention to do minute movements like proceeding, receding and stopping, thus the present invention is extremely suitable for being applied in disposable chips for biochemical reaction tests to drive microfluid; e.g., in biochips for both nucleotide sample processing and DNA-based reaction analyzing, so that samples of the blood and phlegm from patients can be led into the micro-reaction module to be tested and analyzed.

Although the present invention has been described in considerable detail with reference to certain preferred embodiments thereof, those skilled in the art can easily understand that all kinds of alterations and changes can be made within the spirit and scope of the appended claims. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred embodiments contained herein.